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FILING DATE: *October 08, 2002*

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**PROVISIONAL APPLICATION FOR PATENT COVER SHEET**

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

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J0912 U.S. PRO

60/417273

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<input type="checkbox"/> Additional Inventors are being named on the _____ separately numbered sheets attached hereto					
TITLE OF THE INVENTION (280 characters max)					
Detection of Voids in Conductive Materials					
Direct all correspondence to: CORRESPONDENCE ADDRESS					
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OR		Type Customer Number here			
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ENCLOSED APPLICATION PARTS (check all that apply)					
<input checked="" type="checkbox"/> Specification Number of Pages		19		<input type="checkbox"/> CD(s), Number <input type="text"/>	
<input type="checkbox"/> Drawing(s) Number of Sheets		<input type="text"/>		<input type="checkbox"/> Other (specify) <input type="text"/>	
<input type="checkbox"/> Application Data Sheet. See 37 CFR 1.76					
METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT (check one)					
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27.				FILING FEE AMOUNT (\$)	
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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.					
<input checked="" type="checkbox"/> No					
<input type="checkbox"/> Yes, the name of the U.S. Government agency and the Government contract number are:					

Respectfully submitted,  
SIGNATURE

Tarek N. Fahmi

Date 10/8/2002

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REGISTRATION NO. 41,402

(if appropriate) Docket Number: 6317P004Z

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UNITED STATES PROVISIONAL PATENT APPLICATION

For

DETECTION OF VOIDS IN CONDUCTIVE MATERIALS

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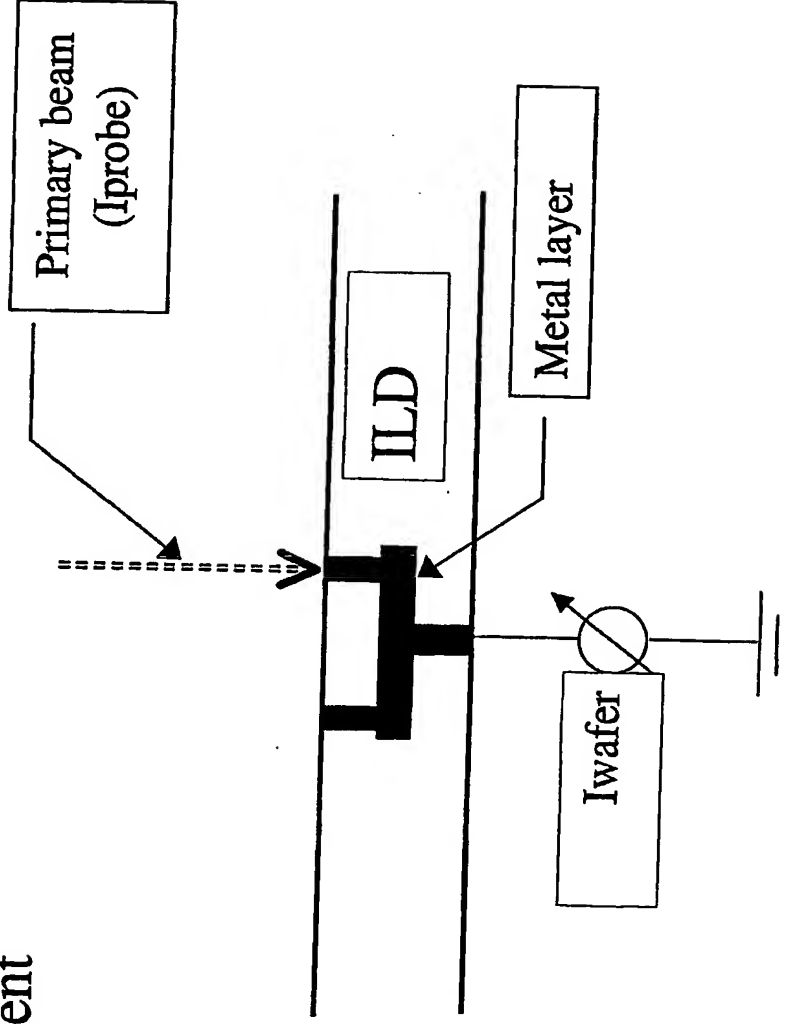
## **DETECTION OF VOIDS IN CONDUCTIVE MATERIALS**

**[0001]** Detection of voids (especially sub-surface) within conductive materials such as copper may be based upon X-ray emission resulting from directing an electron beam to the conductive material. The X-ray emission may be generated during an EDX process. In cases where a conductor is surrounded or at least partially surrounded by non-conductive material (such as silicon oxide), voids cause a change in the spectrum of the emitted x-rays. The change results from the difference in the x-ray emission path resulting from the void. The energy of the electron beam shall enable the penetration of electrons and the emission of x-rays from throughout the conductive material. In such a case the EDX methods may be implemented for measuring the thickness of the conductive and non-conductive material. Such a measurement may be made after CMP polishing, for detecting "dishing", but may be otherwise implemented in areas where there is low probability to have voids. Such a location may be the center of a relatively large conductor (such as a conductive pad) or other parts that are distinct from the walls of the conductive materials.

**[0004]** Improved void detection may be achieved when more than a single detection/propagation paths are utilized. For example, by utilizing detectors for detecting x-rays from distinct angles, or when tilting the inspected object between measurements.

# Possible SEM based methods to locate Cu voids

Wafer Current

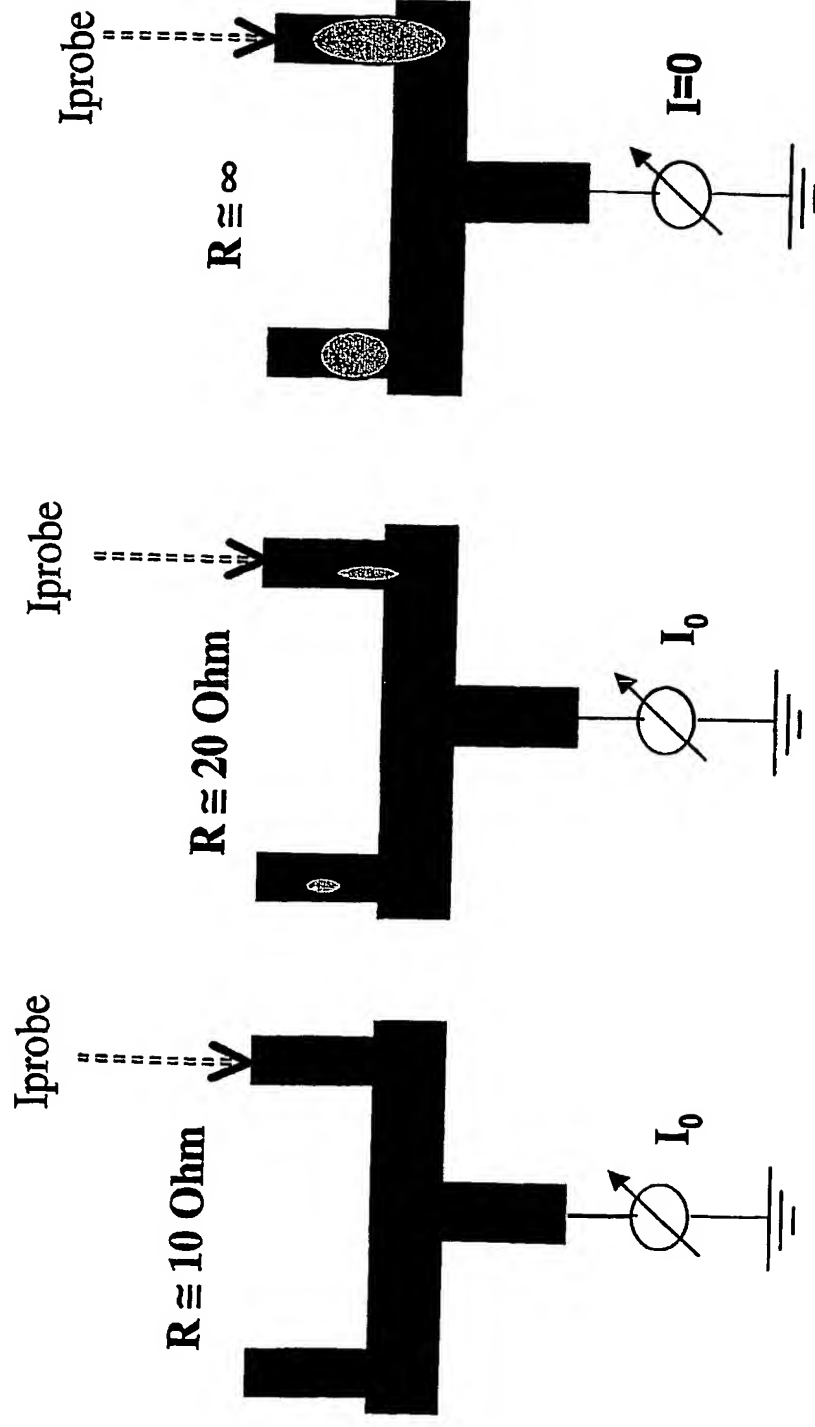


The current through the Cu vias to the ground is measured

# Possible SEM based methods to locate

## Cu voids

Wafer Current

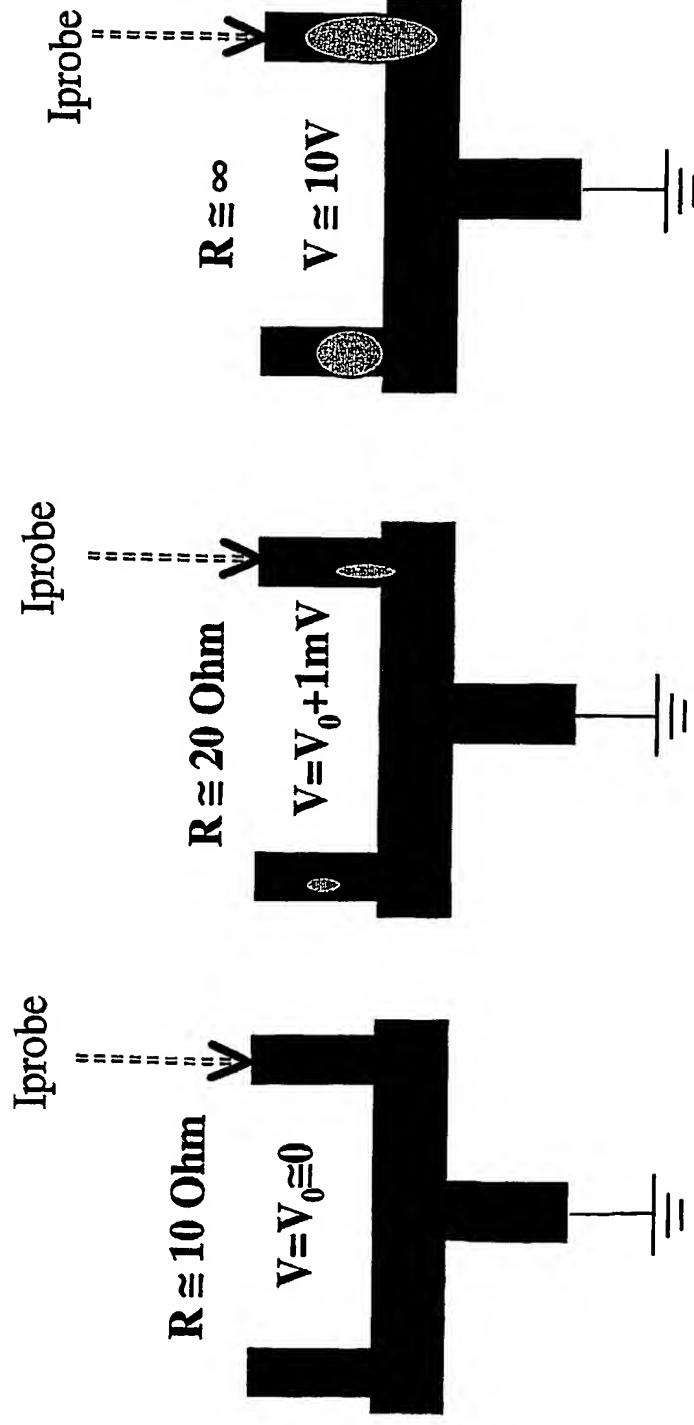


As the electron gun is a current source, the current through the via will be constant as long as the via is conductive. Therefore, partial voids perturbations are undetectable

# Possible SEM based methods to locate

## Cu voids

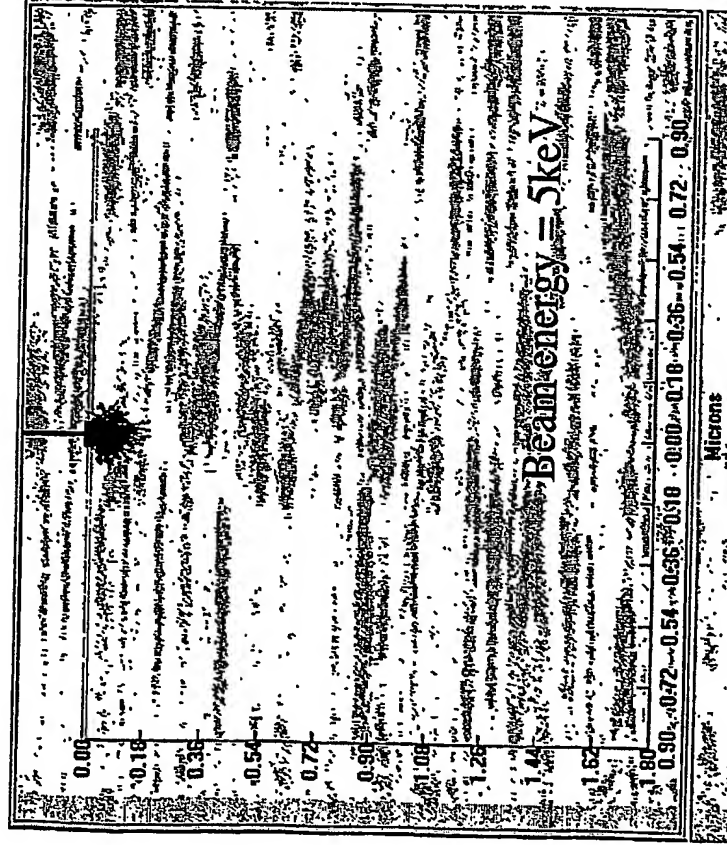
Voltage contrast



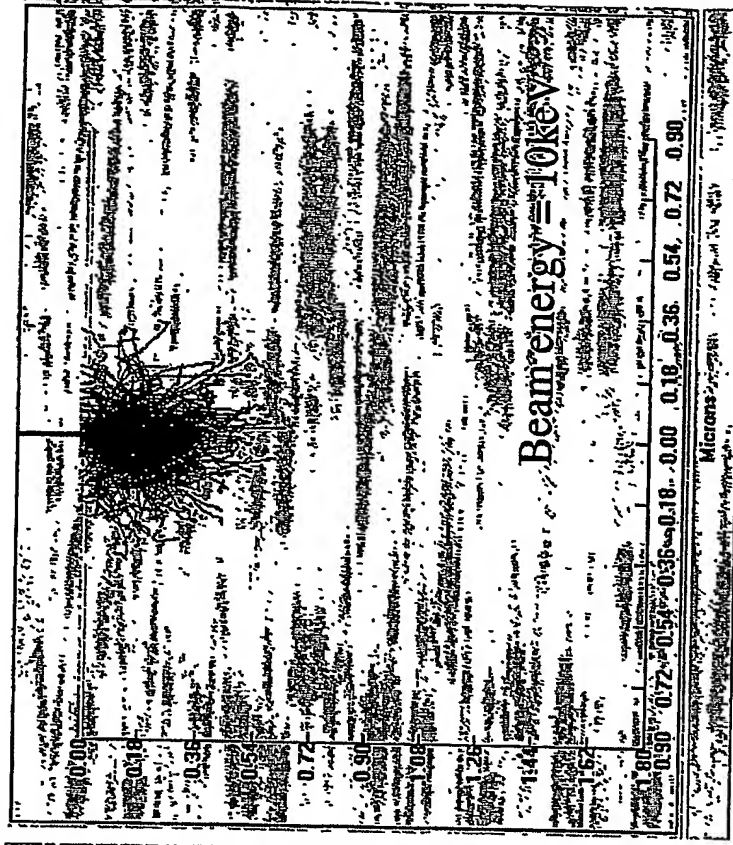
Voltage contrast appears only when the Cu Via is completely isolated. Therefore, Cu voids that do not cause a complete disconnection, cannot be detected.

# Possible SEM based methods to locate Cu voids

EDX Spectrum Analysis - interaction volume



The penetration depth of the  
primary beam is 0.15 microns

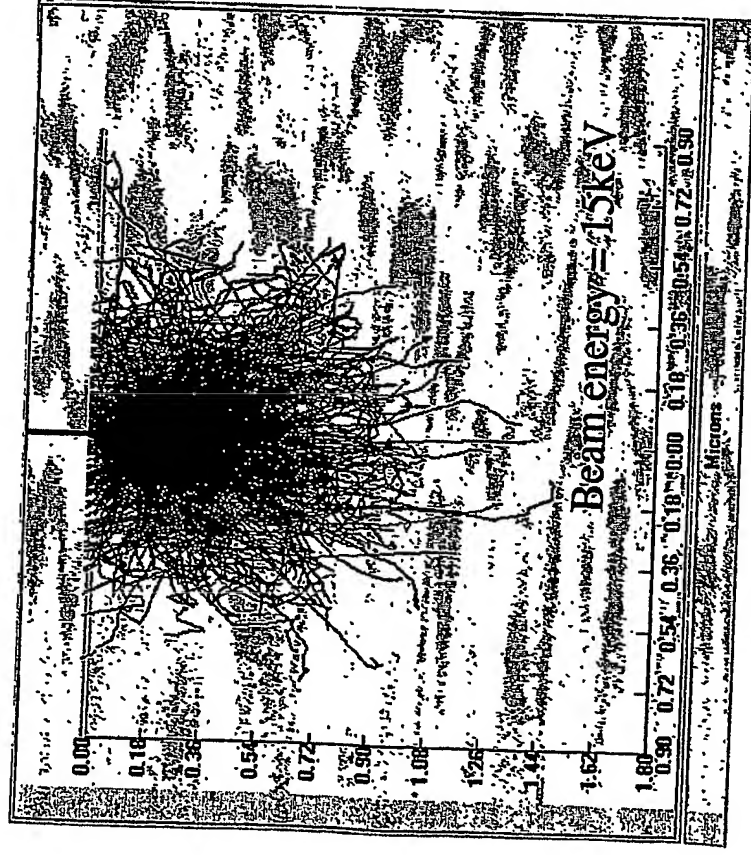


The penetration depth of the  
primary beam is 0.36 microns

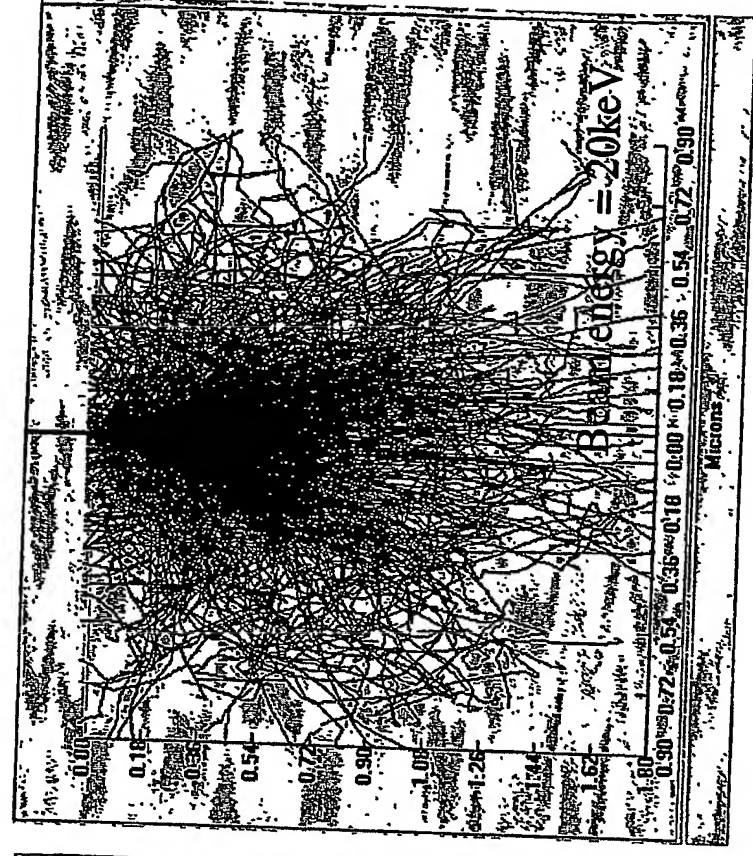


# Possible SEM based methods to locate Cu voids

EDX Spectrum Analysis - interaction volume



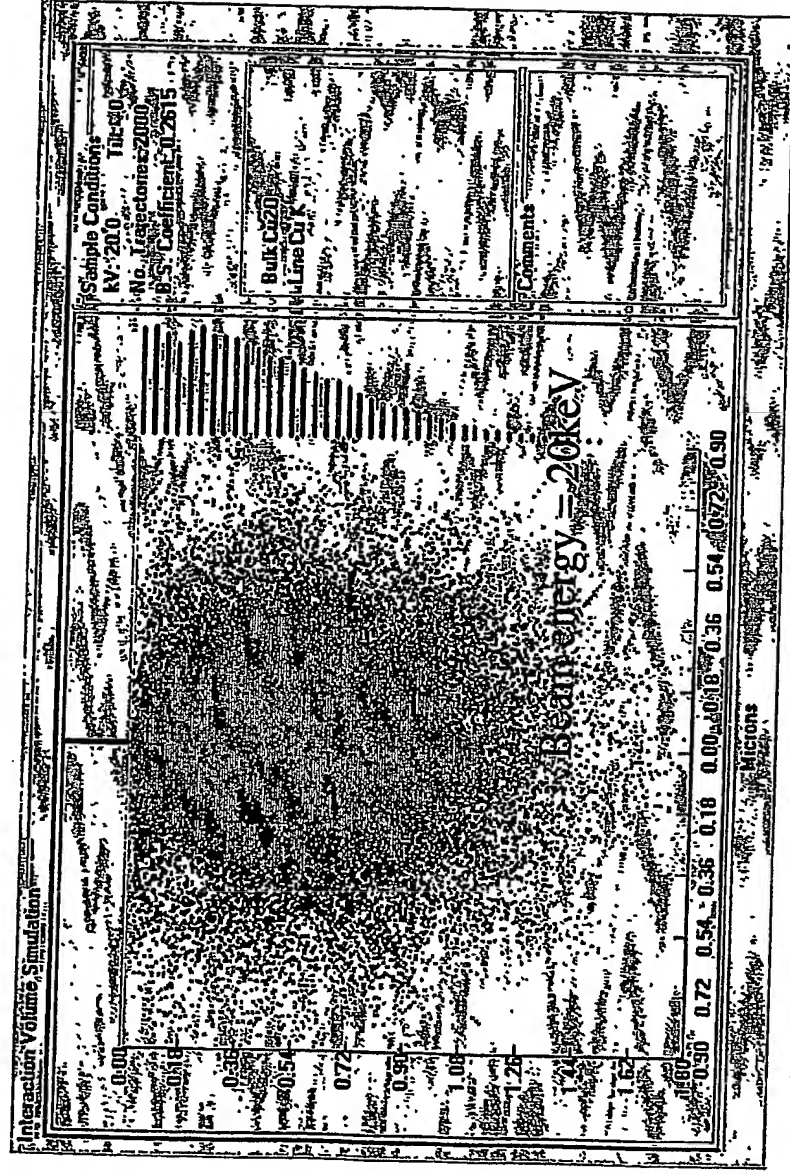
The penetration depth of the  
primary beam is 1 micron



The penetration depth of the  
primary beam is 1.6 microns

# Possible SEM based methods to locate Cu voids

EDX Spectrum Analysis – X ray information volume



Cu K photons escape from 1.4 microns within the Cu bulk

Applied Materials Confidential

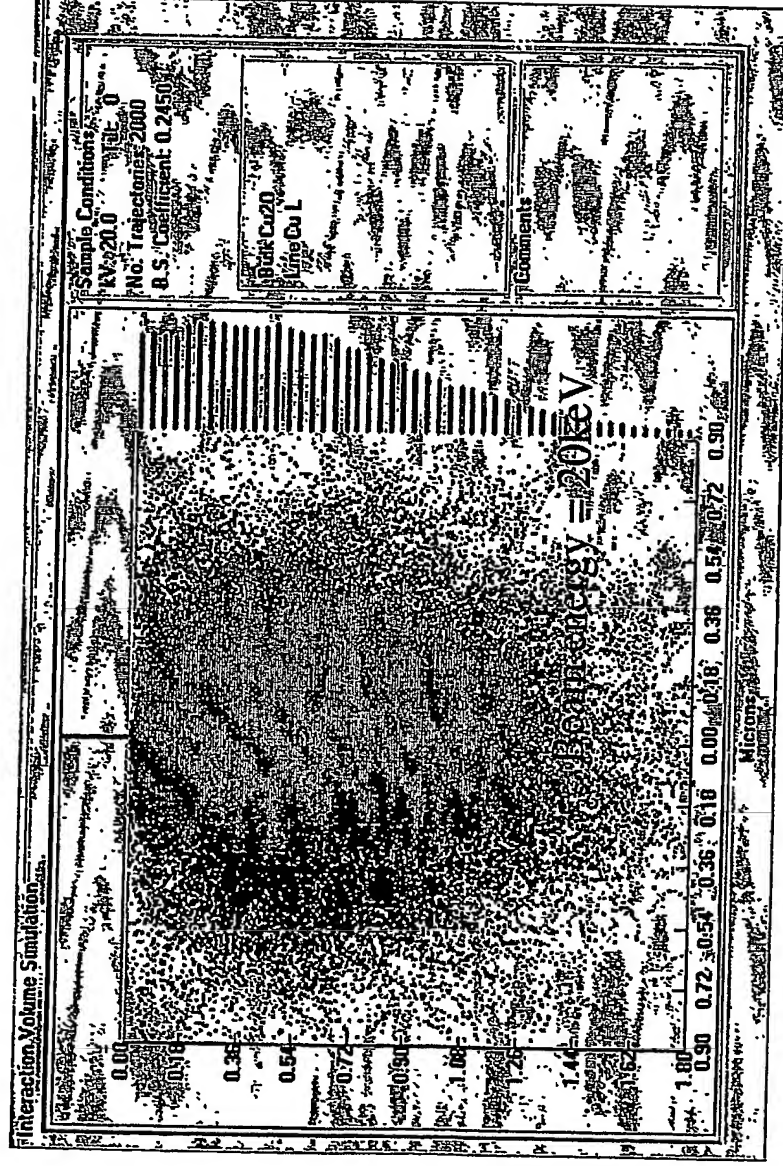
PDC (Process Diagnostic Control)



APPLIED MATERIALS®

# Possible SEM based methods to locate Cu voids

EDX Spectrum Analysis – X ray information volume



Cu L photons escape from 1.7 microns within the Cu bulk

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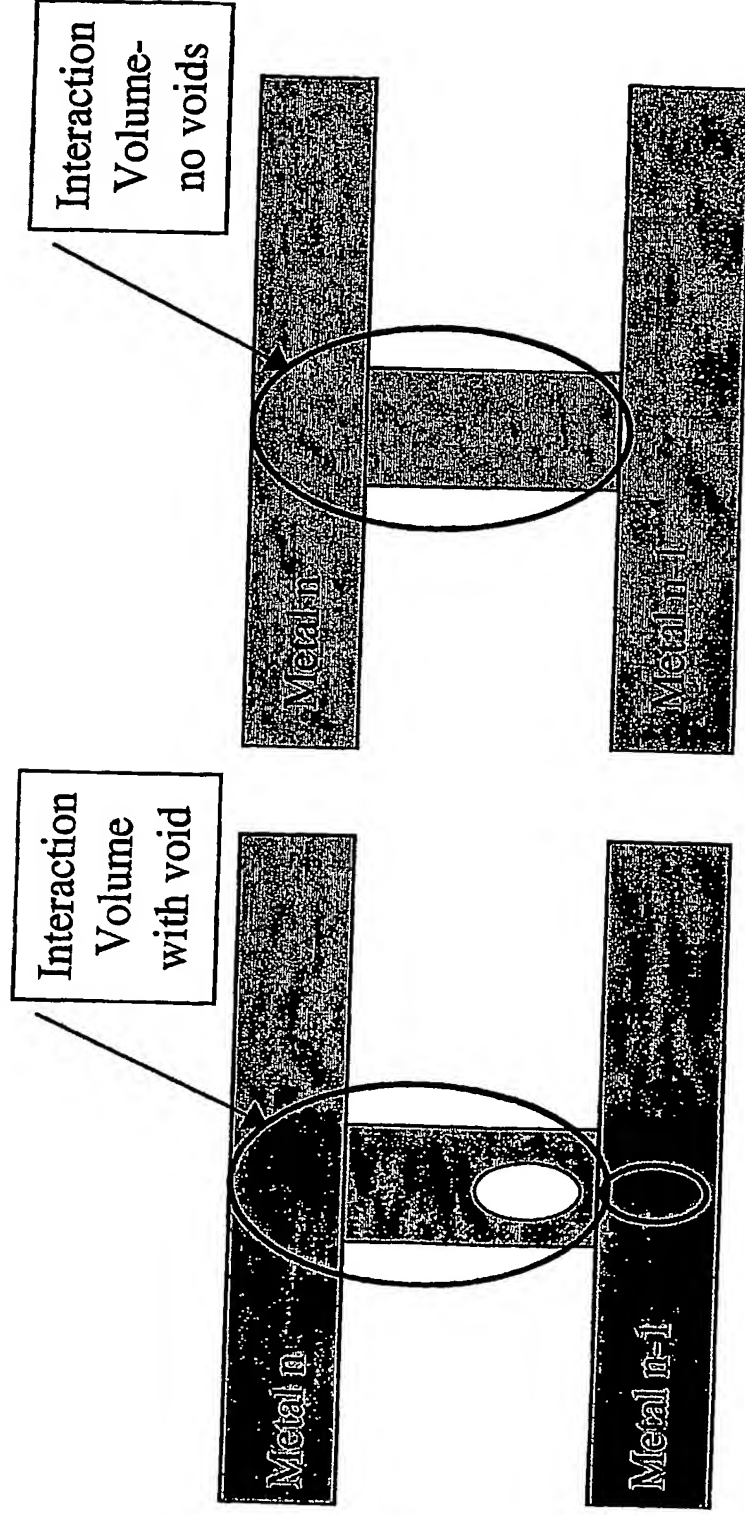
ADG (Process Diagnostics) Division



APPLIED MATERIALS®

# Possible SEM based methods to locate Cu voids

EDX Spectrum Analysis – geometrical considerations



# Possible SEM based methods to locate

## Cu voids

EDX Spectrum Analysis – geometrical considerations

- When voids exist in the Cu via, less x rays are emitted from the via, and more from Metal n-1 layer.
- As X ray signal decreases with the thickness, it will be weaker when voids exist.

# Possible SEM based methods to locate Cu voids

EDX Spectrum Analysis – absorption considerations

$$I = I_0 \cdot e^{-\mu \cdot \rho \cdot t}$$

Where

$\mu$  is mass absorption coefficient

$\rho$  is the density

$t$  is the thickness

# Possible SEM based methods to locate Cu voids

EDX Spectrum Analysis – absorption considerations

- The absorption coefficient  $\mu$  of Cu L line is 1720 cm<sup>2</sup>/g For Cu, and 3893 cm<sup>2</sup>/g for SiO<sub>2</sub>
- The density  $\rho$  is equal to 8.95g/cm<sup>3</sup> for Cu, and 2.63g/cm<sup>3</sup> for SiO<sub>2</sub>.

For  $t = 1$  micron,

$$\frac{I}{I_0}(Cu) = 0.21$$

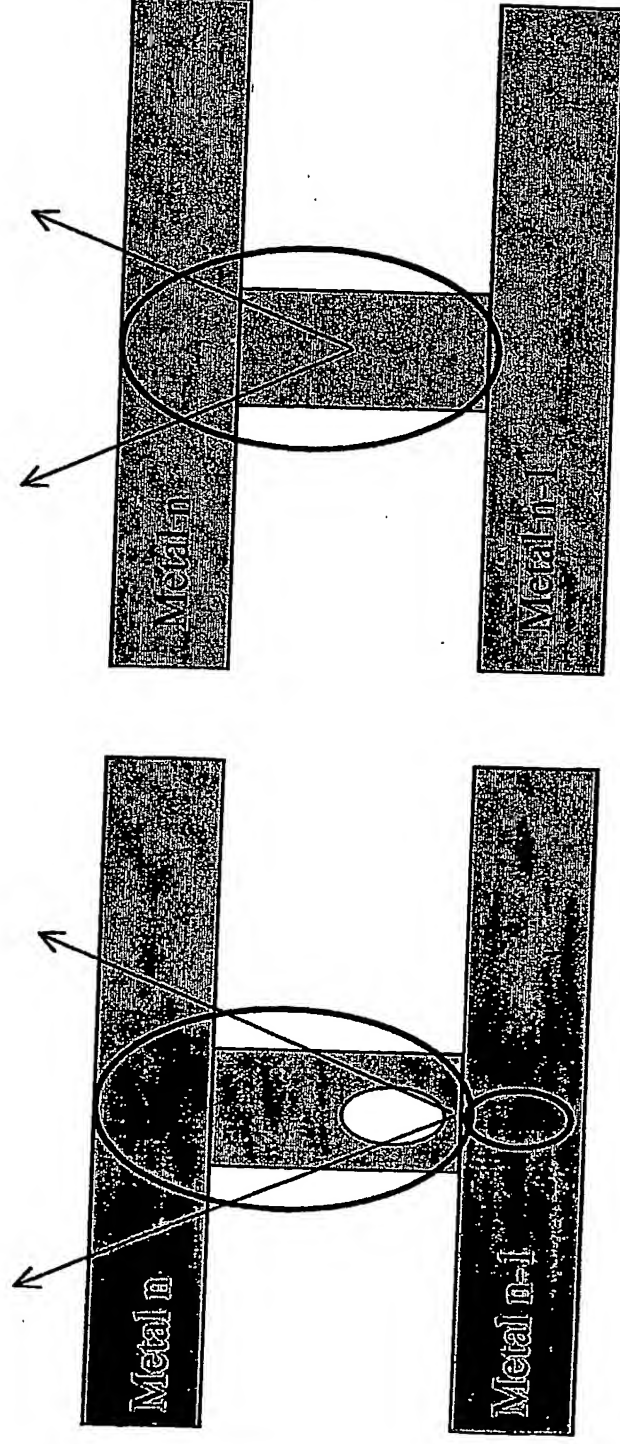
$$\frac{I}{I_0}(SiO_2) = 0.35$$

The absorption of Cu L line in Cu is 1.7 times higher than in SiO<sub>2</sub>



# Possible SEM based methods to locate Cu voids

EDX Spectrum Analysis – absorption considerations



When voids exist, the x-ray photon travels more in the Oxide and less in the Cu, therefore its absorption is smaller



# Possible SEM based methods to locate

## Cu voids

### EDX Spectrum Analysis – summary

- To penetrate into 1.5 micron deep, the beam energy of the SEM should be 20keV.
- The Cu L line carries information from deeper in the Cu via compares to Cu K lines. Therefore, to analyze voids that are deep in the Cu via, L line analysis is preferred.
- From geometrical considerations, the Cu  $L\alpha$  x-ray signal should be lower when voids exists.
- From absorption considerations, the Cu  $L\alpha$  x-ray signal should be higher when voids exists.

# Experimental results and discussion

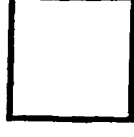
## Column conditions

- The beam energy was set to 20keV. Although the standard Vacc range in the SEMVision G2 is 0.15 to 15kV, it could be set to 20kV without hardware modifications.
- The beam current was set to 400pA. We used the G2 multi hole aperture to achieve this beam current. No HW modifications are required.

# Experimental results and discussion

## Wafer 3 results

- We scanned 20 seconds in FOV 14.6 microns, on the reported location
- We repeated the measurements on many dies across the wafer, and recorded the number of Cu L $\alpha$  counts from each location





# Experimental results and discussion

Wafer 3 results – thickness variations measurements

- To correct for thickness variations, same dies were scanned, on locations where we assumed voids do not exist (for example on large pads).
- On M3 wafer, correlation was found between the thickness variations and the appearance of voids

A side effect of this work - thickness variations of Cu layers can be monitored using x-ray signal analysis

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